ORIGINAL ARTICLE

Ebola Preparedness Resources for Acute-Care Hospitals in the United States: A Cross-Sectional Study of Costs, Benefits, and Challenges

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OBJECTIVE. To assess resource allocation and costs associated with US hospitals preparing for the possible spread of the 2014–2015 Ebola virus disease (EVD) epidemic in the United States.

METHODS. A survey was sent to a stratified national probability sample (n = 750) of US general medical/surgical hospitals selected from the American Hospital Association (AHA) list of hospitals. The survey was also sent to all children's general hospitals listed by the AHA (n = 60). The survey assessed EVD preparation supply costs and overtime staff hours. The average national wage was multiplied by labor hours to calculate overtime labor costs. Additional information collected included challenges, benefits, and perceived value of EVD preparedness activities.

RESULTS. The average amount spent by hospitals on combined supply and overtime labor costs was $80,461 (n = 133; 95% confidence interval [CI], $56,502–$104,419). Multivariate analysis indicated that small hospitals (mean, $76,167) spent more on staff overtime costs per 100 beds than large hospitals (mean, $15,737; $P < .0001$). The overall cost for acute-care hospitals in the United States to prepare for possible EVD cases was estimated to be $361,108,968. The leading challenge was difficulty obtaining supplies from vendors due to shortages (83%; 95% CI, 78%–88%) and the greatest benefit was improved knowledge about personal protective equipment (89%; 95% CI, 85%–93%).

CONCLUSIONS. The financial impact of EVD preparedness activities was substantial. Overtime cost in smaller hospitals was >3 times that in larger hospitals. Planning for emerging infectious disease identification, triage, and management should be conducted at regional and national levels in the United States to facilitate efficient and appropriate allocation of resources in acute-care facilities.

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The 2014–2015 Ebola virus disease (EVD) epidemic in West Africa was the largest known filovirus outbreak, with 28,616 people infected and 11,310 deaths.[1] As the scope of the epidemic escalated over the summer of 2014, healthcare facilities outside of West Africa, including the United States, began preparing for the possibility of managing EVD cases.

In September 2014, the first EVD case in the United States was diagnosed in Dallas, Texas, and subsequently 2 of the patient's nurses became infected.[2] The Centers for Disease Control and Prevention (CDC) initially issued guidance that all US hospitals should be able to care for a patient with EVD.[3] The expectation that all hospitals become capable of screening and managing patients with EVD resulted in considerable anxiety and consternation, along with substantial workload increases and unplanned resource expenditures.[4] The high mortality rate and sensationalistic, round-the-clock news and social media coverage of the epidemic fueled excessive public anxiety in the United States.[5] This angst extended to the medical community, as evidenced by a cross-sectional study of healthcare workers (HCWs) that found that >25% were not willing to care for an EVD patient.[6] Whereas a survey of infectious disease physicians who were part of the Emerging Infections Network (EIN) found that healthcare institutions in the United States were preparing for Ebola cases, some respondents noted they were relatively unprepared.[7]

Hospitals, including those equipped with facilities to treat highly infectious diseases, experienced challenges including scheduling complications due to increased frequency of staff

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training.[8] In December 2014, the CDC identified the first 35 facilities designated as Ebola treatment centers, thus focusing resource allocation and preparation.[9] At that point, US acute-care hospitals were left to independently assess the risk of receiving an EVD patient and to allocate resources accordingly in preparation for possible cases. A survey of Society for Healthcare Epidemiology of America members found that during a sample week in October 2014, Ebola preparation required 80% of hospital epidemiology department time and that 70% of routine infection prevention activities were not completed.[10] We surveyed US acute-care hospitals to quantify the resources allocated to preparing for possible EVD cases during this unprecedented epidemic. The objective of this cross-sectional survey was to assess costs, challenges, benefits, and perceived value of EVD preparedness activities to hospitals across the nation. In assessing the costs, we hypothesized that US hospitals allocated significant resources and experienced challenges in their preparedness efforts and that these costs and challenges disproportionately affected smaller hospitals.

METHODS

A stratified national probability sample comprised of 750 US general medical/surgical hospitals was selected from the March 2015 updated list of hospitals provided by the American Hospital Association (AHA). In addition, all children's general hospitals listed by the AHA (n = 60) were selected, for a total of 810 hospitals. On June 16, 2015, an advance letter was mailed from 3 collaborating organizations (Rhode Island Hospital, Society of Healthcare Epidemiology of America,[10] and The Joint Commission) to chief executive officers (CEOs) of selected hospitals. The advance letter invited their participation in the upcoming survey.

On June 19, 2015, paper questionnaires were sent through the US Postal Service to 195 CEOs for whom email addresses were unavailable. From June 23 to June 25, 2015, links to an electronic version of the questionnaire were emailed to 555 CEOs with available email addresses. The electronic version of the questionnaire was created and administered using the Qualtrics online survey system; the questionnaire can be viewed in the Online Supplement. On July 15 and 16, reminder postcards were sent by ground mail to nonrespondents in the non–email group and by email to nonrespondents in the email group. Paper questionnaires were sent again by ground mail to all nonresponding CEOs September 4 through September 8. In every contact, the CEO was asked to identify a person in the hospital who was most knowledgeable about the EVD preparation activities. That person was invited to gather information from others in the organization as necessary. The survey asked about resources expended from August 2014 through December 2014 related to EVD preparation: actual costs for purchases of disposable and reusable supplies; equipment and infrastructure changes; hours of staff overtime; perceived challenges and barriers; perceived benefits; and perceived overall value. Returned surveys were not excluded based on completeness. Hospital bed size, location, teaching affiliation, and CDC designation were obtained from the AHA. All data collection activities occurred from June to September 2015. The study was approved by the Institutional Review Board (IRB) at Lifespan Health System and the IRB service used by The Joint Commission.

Univariate, bivariate, and multivariate analyses were conducted using the Statistical Analysis System (SAS) version 9.4 (SAS Institute, Cary, NC). Self-reported data regarding overtime staff hours were combined with national wage rates to calculate staff labor costs. Self-reported data regarding purchased supplies were divided by AHA bed size data to obtain costs per 100 beds.

Multivariate regression analyses were used to analyze cost data by the hospital characteristics of bed size (3 categories: less than 100, 100–299, and ≥300 beds), teaching hospital status (3 categories: major teaching hospital, minor teaching hospital, nonteaching hospital), location (2 categories: urban and rural), and the 4 US census regions: Northeast, South, Midwest, and West. Hospitals with ≥300 beds, nonteaching hospitals, rural hospitals, and hospitals located in the West census region were used as the base categories in the multivariate analyses. The multiple regressions were calculated using SAS (9.3) Proc Genmod with distribution = gamma and link = log.

Information about common challenges and perceived benefits was summarized. Overall benefit was summarized across hospitals and by hospital size, as well as cost per 100 beds. Significance was set at $P < .05$.

RESULTS

Of 810 hospitals, 222 (27%) responded to the survey and were included in the study (Table 1). A single survey response was returned with 5 missing pages (one-half of the survey) and was excluded. Another 5 hospitals returned blank surveys with notes declining participation in the study and were classified as nonresponders. Only 1 mailed survey was returned due to incorrect address, and another was returned because the hospital had closed. The responses were from hospitals in 45 states and the District of Columbia, representing a geographic cross section of the United States; only Alaska, Connecticut, Delaware, and Rhode Island were not represented. Response rates did not vary by hospital size, urban/rural location, teaching affiliation or census region (all P values > .05). The response rate for children's general hospitals was lower than for general medical/surgical hospitals (15% vs 28%, respectively; $P = .03$). Using the CDC classification, responses were received from 3 hospitals designated as Ebola treatment centers, 55 Ebola assessment hospitals, and 161 frontline healthcare facilities. The primary survey respondents were the hospital infection preventionists (n = 112; 50%), emergency preparedness-related staff (n = 39; 18%), persons from hospital leadership or administration (n = 33; 15%), and quality improvement–related staff (n = 23; 10%) in conjunction with representatives

TABLE 1. Preparing US Acute-Care Hospitals for Ebola Virus Disease: Hospital Characteristics

Characteristic	Variable	Targeted Sample[a]	No. Respondents[b]	% Responses
Hospital bed size	<100	390	104	26.7
	100–299	271	77	28.4
	300+	143	40	28.0
Teaching affiliation	Major	51	14	27.5
	Minor	188	51	27.1
	None	565	156	27.6
Location	Urban	470	126	26.8
	Rural	334	95	28.4
Hospital type	General medical/surgical	750	211	28.1
	Children's general	60	9	15.0
Census region	Northeast	97	28	29.0
	Midwest	235	69	29.0
	South	313	78	25.0
	West	165	45	27.2

[a]Targeted sample sums to 804 for hospital bed size, teaching affiliation, and location because 6 hospitals had missing variables for these values on the AHA file.
[b]Number responded sums to 221 for hospital bed size, teaching affiliation, and location because 1 hospital with missing variables for these values responded to the survey.

TABLE 2. Preparing US Acute-Care Hospitals for Ebola Virus Disease: Overall Supply, Staff Overtime (OT), and Combined Costs

Cost per Hospital	N	Mean	Std Dev	95% CI	Median	Minimum	Maximum
Total supply costs	147	$42,798	$98,642	$26,719–$58,877	$7,948	$214	$593,034
Total staff OT costs	194	$31,540	$61,242	$22,868–$40,212	$14,174	$291	$647,064
Total combined costs	133	$80,461	$139,681	$56,502–$104,419	$35,354	$1,457	$760,367
Total costs per 100 beds	146	$15,787	$28,022	$11,204–$20,371	$6,642	$159	$250,000
Supply costs per 100 beds	193	$44,889	$161,195	$22,003–$67,775	$11,448	$117	$1,559,675
OT costs per 100 beds	132	$51,519	$138,063	$27,746–$75,291	$24,512	$431	$1,528,763
OT Costs per 100 Beds by Hospital Size	**N**	**Mean**	**Std Dev**	**95% CI**	**Median**	**Minimum**	**Maximum**
Less than 100 beds	85	$84,951	$236,947	$33,842–$136,059	$28,004	$483	$1,559,675
100–299 beds	73	$13,354	$14,791	$9,903–$16,805	$7,324	$314	$83,497
≥300 beds	35	$13,367	$19,741	$6,586–$20,148	$8,203	$117	$110,989
Hospital location							
Urban	111	$52,194	$208,289	$13,015–$91,374	$10,220	$117	$1,559,675
Rural	82	$35,000	$50,020	$24,009–$45,990	$16,395	$789	$287,658
Hospital teaching affiliation							
Major	12	$15,685	$13,326	$7,218–$24,151	$9,096	$254	$39,412
Minor	45	$27,659	$43,670	$14,539–$40,779	$10,738	$314	$218,902
Nonteaching	136	$53,167	$189,934	$20,957–$85,377	$12,378	$117	$1,559,675

from finance, human resources, and purchasing departments. The aforementioned response sums do not add up to 222 due to incomplete survey responses.

Table 2 shows that from August 1 to December 31, 2014, for the 133 hospitals that reported both supply costs and overtime hours, the mean combined cost was $80,461 (n = 133; standard deviation [SD], $139,681; 95% confidence interval (CI), $56,502–$104,419). The mean disposable and reusable supply cost per reporting hospital was $42,798 (n = 147; SD, $98,642; 95% CI, $26,719–$58,877). Table 3 shows that nurses had the highest mean overtime hours (428 hours), more than double any other individual staff type. An estimated national total cost of $361,108,968 was determined by multiplying the mean combined cost of $80,461 by the 4,488 eligible US acute-care hospitals in our sample.

Separate multivariate analyses were conducted with total supply costs and cost of staff overtime as outcome variables. Only statistically significant comparisons are noted. Results indicated that hospitals in the 100–299-bed category (mean, $39,528) and those in the ≥300-bed category (mean, $134,657) spent more on supplies than those in the <100-bed category (mean, $5,827; both P values < .0001). Major teaching hospitals (mean, $280,874) spent more on

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TABLE 3. Preparing US Acute-Care Hospitals for Ebola Virus Disease: Overtime Hours by Staff Type

Staff Type	Mean, h	Median, h	Minimum, h	Maximum, h	No. of Hospitals
Physicians	93.7	20.0	0.5	3,060	108
Physician assistant, nurse practitioner, advanced practice nurses	40.5	8.0	1.0	1,200	53
Nurses	428.0	148.0	1.5	7,819	158
Clinical managers, department heads or directors (includes infection preventionist)	203.0	80.0	1.5	3,060	154
Laboratory staff	48.1	16.0	1.0	1,000	97
Respiratory technicians/technologists	53.5	20.0	1.0	1,520	87
Environmental service workers	60.9	20.0	1.0	1,792	107
Security staff	110.8	20.0	1.0	4,000	70
Administrative staff	152.9	40.0	1.5	4,000	123
Registration/front desk, other support	31.3	20.0	1.0	224	89
Other	510.0	64.5	20.0	4,060	12

supplies than did nonteaching hospitals (mean, $18,125; $P<.0001$). Multivariate regression analysis indicated that hospitals with <100 beds spent more on staff overtime per 100 beds (mean, $76,167) than did hospitals with ≥300 beds (mean, $15,737; $P<.0001$). Urban hospitals spent more on staff overtime per 100 beds (mean, $43,913) than did rural hospitals (mean, $40,191; $P=.0002$). Multivariate analysis also indicated that major and minor teaching hospitals spent more on staff overtime (mean major, $139,936; $P=.02$; mean minor, $51,109; $P=.01$) than did nonteaching hospitals (mean, $20,333). Urban hospitals spent more on staff overtime (mean, $50,754) than did rural hospitals (mean, $13,544; $P<.0001$). Overall, 194 of the 222 hospitals (87%; 95% CI, 0.83–0.91) reported purchasing at least 1 disposable or reusable item (Table 4). The most commonly purchased disposable items were those offering face, body, foot, and hand protection.

Table 5 shows that the most frequently perceived challenges reported in the survey included difficulty obtaining supplies from vendors due to shortages (83%; 95% CI, 78%–88%), managing HCW anxiety and fear (67%; 95% CI, 61%–73%), and dealing with conflicting federal, state or local guidance (66%; 95% CI, 60%–72%). Table 5 shows that the most frequently perceived benefits included improved personal protective equipment knowledge and use (89%; 95% CI, 85%–93%), better screening and triage procedures (80%; 95% CI, 75%–85%), and better preparation for management and containment of future infectious diseases (75%; 95% CI, 69%–81%). Comparing costs, challenges, and benefits, respondents' assessment of the overall value of EVD preparedness procedures was positive. Most respondents (86%; 95% CI, 81%–91%) reported a moderate, major, or extreme perceived overall value of EVD preparedness activities, whereas 1% (95% CI, 0%–2.0%) reported no perceived value. Perceived positive overall value (moderate, major, or extreme) was significantly associated with hospital size but not with total amount spent for supplies and overtime staff per 100 beds. The vast majority of respondents reported positive overall value of the EVD preparation (Figure 1).

TABLE 4. Preparing US Acute-Care Hospitals for Ebola Virus Disease: Supplies Purchased, Disposable and Reusable

	No. of hospitals (%) (N = 222)	95% CI, %
Supplies Purchased, Disposable		
Purchased any supplies or equipment	194 (87)	82–91
Face protection	187 (84)	79–88
Coveralls	183 (82)	76–87
Shoe/leg coverings	162 (73)	67–78
Gloves	155 (70)	63–76
Respirators	102 (46)	39–52
Environmental cleaning solutions	88 (40)	33–46
Biohazard spill kits/bags	84 (38)	31–44
Hand-hygiene supplies	83 (37)	30–43
Transport equipment/supplies	54 (24)	18–29
Other	51 (23)	17–28
Triple packing system	50 (23)	17–28
Leak proof body bags	29 (13)	8–17
Supplies Purchased, Reusable		
Rigid waste containers/PPE carts	83 (37)	30–43
Software modifications to EMR	70 (32)	25–38
Powered air-purifying respirators	52 (23)	17–28
Washable footwear	50 (23)	17–28
Moderate construction	47 (21)	15–26
Lab supplies/equipment	40 (18)	12–23
Electronics	36 (16)	11–20
Other	21 (9)	5–12

DISCUSSION

To our knowledge, this is the first study that has attempted to assess costs and benefits of EVD preparedness activities in a nationally representative sample of US acute-care hospitals. A simple extrapolation of combined supplies and overtime costs suggests that the attributable cost for acute-care hospitals in the United States to prepare for possible EVD cases was approximately $360 million. Of the 11 cases of EVD treated in the United States, only 4 were diagnosed

TABLE 5. Challenges and Benefits of Preparing US Acute-Care Hospitals for Ebola Virus Disease.

	No. of hospitals (%), (N = 222)	95% CI, %
Challenges		
Difficulty obtaining supplies	185 (83)	78–87
Managing HCW anxiety and fear	148 (67)	60–73
Conflicting/changing public health guidance	146 (66)	59–72
Lack of time to plan/execute training	111 (50)	43–56
Lack of adequate staffing	102 (46)	39–52
Lack of regional care centers	85 (38)	31–44
Problems coordinating with external groups	51 (23)	17–28
Problems with internal team communication	32 (14)	9–18
Other	21 (9)	5–12
Benefits		
Improved PPE knowledge and use	197 (89)	84–93
Better screening and triage procedures	178 (80)	74–85
Better prepared for future infectious events	167 (75)	69–80
Increased awareness and understanding of infection control	162 (73)	67–78
Improved internal team building and communication	136 (61)	54–67
Improved bioterrorism/disaster preparedness	127 (57)	50–63
Improved coordination with external groups	122 (55)	48–61
Improved compliance with isolation precautions	120 (54)	47–60
Enhanced recognition of IPs and hospital epidemiologist	113 (51)	44–57
Improved general infection prevention practices	104 (47)	40–53
Improved hand hygiene	67 (30)	23–36
Other	8 (4)	1–6

NOTE. HCW, healthcare worker; PPE, personal protection equipment; IP, infection preventionist.

outside of West Africa in US hospitals. Thus, acute-care hospitals in the United States cumulatively spent approximately $90 million in preparation for each of the 4 EVD patient diagnosed domestically. Our analysis showed highly significant differences in overtime costs, with smaller hospitals spending >3 times more per 100 beds than larger hospitals. This finding illustrates the disproportionate impact that EVD preparation had on smaller hospitals with fewer resources.

Despite substantial challenges faced and money and time spent on EVD preparedness, respondents generally perceived benefits related to preparation. Overall, our findings suggest that the experience should help our nation's hospitals be more resilient and better prepared for not only emerging infectious diseases but also routinely encountered infectious pathogens. Other studies have found these perceived benefits in EVD preparedness activities. In a survey conducted in 2015 by the Association for Professionals in Infection Control and Epidemiology, 902 of 981 of US hospital–based members (92%) believed their facilities to be more prepared to handle a patient with infectious diseases such as EVD.[11] However, more than half of the members surveyed (55%) stated that their facility had not allocated ongoing resources to maintain this readiness.[11]

Our findings may be limited by recall bias due to the retrospective study design. Cost data were missing for almost one-third of respondents who reported purchasing supplies. If purchasing was done at the hospital system level, some respondents noted that they could not parse out costs incurred

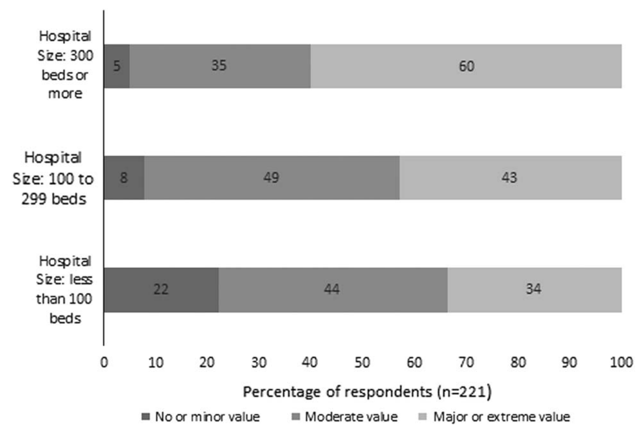

FIGURE 1. Hospital survey responders' perceived overall value of Ebola virus disease (EVD) preparation by hospital bed size.

by their hospital. Cost estimates do not include costs of training or EVD activities during regular working hours. The cost estimates in this study may represent a significant underestimate of actual time spent preparing for possible EVD cases because many training activities were likely done during regularly scheduled work shifts.

Preparing for infectious disease outbreaks and epidemics is challenging for the large, decentralized healthcare systems in the United States. Countries with a more centralized healthcare system may more easily focus resources and

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effectively plan for isolation and treatment of such cases.[8,12,13] A survey sent to the 55 CDC-designated Ebola treatment centers in April 2015 revealed that although preparedness nationwide was higher, significant limits in patient capacity existed.[14] Given the vast resources needed to isolate and treat even a few patients, this is not surprising. A thoughtful review by the staff at the Dallas, Texas, facility that was the first community hospital to diagnose and treat a patient with EVD identified engineering and administrative controls, as well as PPE training, as key building blocks to safely treat a patient with EVD.[15] Indeed, these building blocks can be used to prepare for future infectious disease outbreaks. In all likelihood, the next major infectious disease threat to the United States will be a disease other than EVD, and preparing for the next outbreak should be done with the admission and acceptance that there will be an element of the unknown to overcome. To optimize this preparation, planning for emerging infectious diseases identification, triage, and management should be conducted at regional and national levels to facilitate efficient and appropriate allocation of resources without compromising key day-to-day activities such as infection control and hospital epidemiology in community healthcare facilities.

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SUPPLEMENTARY MATERIAL

To view supplementary material for this article, please visit https://doi.org/10.1017/ice.2017.6

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